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AN EVALUATION OF THE FUEL OIL ADDITIVE CV-100 UNIVERSAL COMBUSTION CATALYST

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by

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ABSTRACT

A series of tests to evaluate the fuel oil additive CV-100 were conducted in a small package boiler using No. 2 distillate and No. 6 residual fuel oils as reference fuels. During the tests, each of which were of 48-hours duration, SO_2, NO, smoke emission and soot deposition were measured along with relevant combustion performance parameters.

No changes were detected which could be attributed to the use of the additive.

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INTRODUCTION

Widespread consumer interest in improved fuel efficiency and energy conservation has resulted in the marketing of numerous proprietary chemicals which claim to reduce oil consumption by minimizing smoke emissions and by removing soot deposits from boiler heat transfer surfaces.

To provide quantitative data on the effects of one of these additives, a laboratory evaluation of the fuel oil additive known as CV-100 Universal Combustion Catalyst, was carried out in a small packaged oil-fired boiler under combustion and operating conditions representative of those existing in industrial steam boilers. The evaluation was carried out as a component part of the CANMET Energy Research Program in collaboration with the Director-General Works, Department of National Defense.

This report describes the facilities and procedures used to test the CV-100 fuel-oil additive and gives an evaluation of the experimental data.

THE OIL-FIRED PACKAGED BOILER

The boiler used for this additive evaluation was a "Cyclotherm" fire-tube steam generator equipped with an axially-mounted, pressure-jet oil burner capable of burning either No. 2 or No. 6 fuel oil to provide a thermal input of 350,000 Btu/hr (approximately 2 Igph of oil). Figure 1 shows a schematic illustration of the boiler and fuel supply system which was instrumented and tested in accordance with the American Society of Mechanical Engineers (ASME) Abbreviated Boiler Efficiency Test (PTC 4.1a - 1964). To provide a constant steam load throughout each test, the entire steam output was passed through an air-cooled heat exchanger. The condensate flow rate was measured routinely prior to discharge.

Fuel oil was supplied to the burner from a 200-gallon tank mounted on an electronic weigh scale. The tank contained electric heaters for preheating residual fuel oil and a mechanical blender for ensuring a uniform supply of either untreated or additive-treated fuel oil.

The package boiler, although instrumented for automatic operation, was manually controlled throughout each combustion test to ensure that all control parameters were maintained within specified limits.

FUEL CHARACTERISTICS

The No. 2 and No. 6 fuel oils used for this additive evaluation were each supplied from single tanker shipments and the bunkered quantities of both fuels were in excess of that required to duplicate each test.

Representative analyses of the No. 2 and the No. 6 fuel oil burned during each test were provided by the Petroleum and Gas Laboratory of the Energy Research Laboratories. These analyses are shown in Table 1.

ADDITIVE DESCRIPTION

CV-100 Universal Combustion Catalyst is advertised by the manufacturers, Carven Petrochemical Co. Ltd., for use with all grades of liquid hydrocarbon fuels. The additive which is probably a solution of iron and picric acid in toluene, is a clear, yellow liquid and its metal container bears labels prescribed for poison and explosive material. This liquid can also cause severe skin irritation and should be labelled accordingly.

A sample of the additive as supplied by the manufacturer to the Canadian Combustion Research Laboratory (CCRL) was submitted to the Petroleum and Gas Laboratory of the Energy Research Laboratories (ERL) for analysis and the results are shown in Table 2.

All tests with additive-treated fuel oil were conducted using the manufacturer's recommended dosage rate of 1 gallon of additive per 1500 gallons of fuel oil. The additive was added to the fuel oil supply tank and blended with a mechanical mixer for 2 days prior to commencement of each additive test. Table 2 indicates that the concentration of the iron active ingredient was about 14 ppb after this blending procedure. Concentrations of this magnitude are lower than the concentrations of the elemental impurities found in typical fuel oils and are therefore unlikely to influence combustion reactions measureably.

EXPERIMENTAL PROCEDURES

The experimental conditions selected for this additive evaluation were finalized following a series of meetings and an exchange of correspondence with the additive manufacturer. Accordingly, a series of cyclic combustion tests were carried out over a 48-hour period with each cycle consisting of 235 minutes "ON" and 5 minutes "OFF". By mutual agreement, this repetitive "ON-OFF" cycle mode and less than optimum combustion conditions were selected because benefits from using the additive are claimed to be greatest when the rates of smoke emission and soot deposition are high enough to reduce boiler efficiencies noticeably. Details of the different tests using No. 2 distillate and No. 6 residual fuel oils are summarized in Table 3.

At the end of each test the boiler was vacuumed clean and the soot collected weighed and analyzed to obtain the amount of unburned carbon deposited during the test period. The heat loss due to carbon deposition and carry-over was calculated by dividing the calorific value of the total carbon collected by the calorific value of the total fuel burned.

To ensure that the boiler operation was typical of deteriorating or poor combustion conditions, the excess combustion air level was adjusted to a reproducible smoke spot index for all tests. Since it was desirable to operate during the tests with higher than normal soot production it was not possible to use the standard Bacharach scale for control purposes. However, a reproducible smoke spot index was possible using the Bacharach instrument by reducing the sample volume abstracted by 90%.

Test Measurements

The following parameters of combustion performance were measured during each test at the locations shown in Figure 1.

1. Carbon dioxide and carbon monoxide continuously by non-dispersive infra-red analyzers, Station C.
2. Oxygen continuously by paramagnetic analyzer, Station C.

3. Nitrogen oxides continuously by chemiluminescent analyzer, Station C.

4. Sulphur oxides intermittently twice daily by modified Shell-Thornton Method, Station B.

5. Smoke spot index, intermittently at least hourly by Bacharach Smoke Tester, Station A.

6. Particulate loading intermittently every four hours by isokinetic dust sampler, Station B.

7. a) Flue gas temperature by thermocouple at Station A.

   b) Combustion air temperature by thermocouple at the combustion air fan inlet.

   c) Oil temperature by thermocouple in oil line immediately before burner.

8. Oil flow rate continuously by electronic weighing of the bunker.

In addition to the critical combustion parameters, a number of supplementary measurements were taken to provide an immediate indication of any discrete changes in boiler operating conditions. These measurements included steam pressure, steam and supply water temperatures, water flow rate to the boiler, burner windbox pressure, furnace draft and oil pressure.

EXPERIMENTAL DATA AND DISCUSSION

The experimental data for steady-state combustion were analyzed statistically and the few outlying data points that fell outside of the expected normal range were discarded(1). The remaining data points, comprising over 95% of the recorded information were averaged for each parameter and are summarized in Table 4 and 5.

As shown in Table 5 the effect of adding CV-100 to No. 2 and No. 6 fuel oils at the recommended dosage rate produced little or no change in either boiler efficiency, combustion performance, smoke emissions or soot deposition rates. These findings confirm the results of earlier flame and heat transfer studies conducted in the CCRL calorimetric furnace(2).

CONCLUSIONS

The treatment of No. 2 and No. 6 fuel oils with CV-100 fuel oil additive have shown no significant changes in either the generation of soot or in fuel efficiency during closely controlled tests in a small packaged boiler.

The baseline conditions used for comparison were typical of poorly operated boilers and provided an ideal environment for the additive to reduce smoke emissions and to remove existing soot deposits. Gas -borne and deposited soot values were essentially unaffected by additive-treatment and any catalytic reactions due to the additive active ingredient must therefore have been either masked by indigenous fuel impurities or too weak to accelerate soot burn-out.

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TABLE 1

FUEL OIL ANALYSIS [1)]

Analysis \ Fuel	No. 2 Oil	No. 6 Oil
Specific Gravity, 60/60°F	0.849	0.955
Gross Calorific Value Btu/lb	19,337	18,412
Carbon, wt %	86.97	86.66
Hydrogen, wt %	12.75	10.67
Nitrogen, wt %	0.01	0.22
Sulphur, wt %	0.50	1.86

1) Analyses performed by the Petroleum and Gas Laboratory, Energy Research Laboratories, CANMET, Department of Energy, Mines and Resources, Ottawa, Canada

TABLE 2

CV-100 ANALYSIS [1)]

Analysis	Value
Carbon, wt %	86.09
Hydrogen, wt %	9.23
Nitrogen, wt %	0.08
Iron, wt ppm	21
Calcium, wt ppm	< 1
Sulphur, wt ppm	< 1
Potassium, wt ppm	< 1
Manganese, wt ppm	< 1
Zinc, wt ppm	< 1
Copper, wt ppm	< 1
Viscosity, cs at 100°F	0.61
Flash Point, °F	< 32
Water, wt %	nil
Specific Gravity 60/60°F	0.855
Calorific Value, Btu/lb	17,417

1) Analyses performed by the Petroleum and Gas Laboratory, Energy Research Laboratories, CANMET, Department of Energy, Mines and Resources, Ottawa, Canada.

TABLE 3

SUMMARY OF TEST VARIABLES

Test No.	Fuel Oil	Additive Treatment vol/vol of Oil	Condition Boiler Fireside Surfaces at Start of Test	Test Rationale
1	No. 2	None	Clean	To obtain baseline data on boiler and combustion performance with untreated No. 2 oil.
2	No. 2	1/1500	Clean	To assess improvements in boiler and combustion performance due to the use of additive-treated No. 2 oil using Test No. 1 as a reference for comparison.
3.	No. 2	1/1500	Dirty	To assess the efficieny of additive-treated No. 2 oil in removing existing soot deposits produced by combustion conditions identical to those used in Test No. 1.
4.	No. 6	None	Clean	To obtain baseline data on boiler and combustion performance with untreated No. 6 fuel oil.
5.	No. 6	1/1500	Clean	To assess improvements in boiler and combustion performance due to the use of additive-treated No. 6 oil using Test No. 4 as a reference for comparison.
6.	No. 6	1/1500	Dirty	To assess the efficiency of additive-treated No. 6 fuel oil in removing soot deposits produced by combustion conditions identical to those used in Test No. 4.
7.	No. 6	None	Dirty	To obtain baseline data on dirty boiler and combustion performance with untreated No. 6 fuel oil.

TABLE 4

SUMMARY OF BOILER OPERATING DATA

Test No.	1	2	3	4	5	6	7
Fuel	No. 2	No. 2	No. 2	No. 6	No. 6	No. 6	No. 6
Additive	No	Yes	Yes	No	Yes	Yes	No
Initial Boiler Condition	Clean	Clean	Dirty	Clean	Clean	Dirty	Dirty
Test Duration, h*	48	48	48/48	48	48	48/48	48/48
Steam Conditions							
Pressure, psig	7.0	6.8	6.5	6.2	6.4	7.0	6.3
Temperature, °F	222	220	216	218	218	220	219
Water Conditions							
Supply Temperature, °F	68	70	68	66	66	66	65
Condensation Return, °F	95	97	90	91	85	91	97
Make-up, Igph	10.9	10.4	11.2	14.4	14.4	13.9	15.1
Oil Conditions							
Pressure, psig	110	110	110	374	345	354	350
Temperature, °F	82	84	73	240	245	243	241
Flow Rate, lb/h	12.7	12.7	12.7	18.9	19.6	17.8	17.4
Furnace Draft, in. WG	0.05	0.05	0.04	0.06	0.06	0.06	0.05
Windbox Pressure, in. WG	3.0	2.9	2.8	6.8	6.5	6.6	4.1

*1st 48 hours with untreated oil to produce dirty boiler surfaces; additive-treated oil burned for 2nd 48 hours.

TABLE 5

SUMMARY OF COMBUSTION CONDITIONS

Test No.	1	2	3	4	5	6	7
Fuel	No. 2	No. 2	No. 2	No. 6	No. 6	No. 6	No. 6
Additive	No	Yes	Yes	No	Yes	Yes	No
Initial Boiler Condition	Clean	Clean	Dirty	Clean	Clean	Dirty	Dirty
Test Duration, h*	48	48	48/48	48	48	48/48	48/48
Flue Gas Analysis							
CO_2, % vol	8.5	8.2	7.7	8.3	8.2	8.6	8.4
O_2, % vol	9.9	10.3	10.7	10.7	10.9	10.3	9.8
CO, % vol	0.05	0.05	0.05	0.05	0.08	0.07	0.05
NO, ppm vol	-	32	26	113	97	110	110
SO_2, ppm vol	138	145	151	397	383	388	341
Soot Loading, mg/sm^3	110	113	113	274	288	309	286
Flue Gas Temp, °F	426	498	425	621	612	612	670
Combustion Air Temp, °F	95	93	88	88	70	95	90
ASME Heat Balance							
Dry Flue Gas Loss, %	10.4	13.2	11.7	18.0	18.5	18.3	19.4
Hydrogen Loss, %	7.1	7.3	7.1	6.7	6.8	6.8	6.8
CO Loss, %	0.1	0.1	0.1	0.2	0.2	0.2	0.2
Unburnt Carbon Loss, %	0.4	0.3	0.4	1.2	1.3	1.0	0.9
Indirect Efficiency, %	82.0	79.1	80.7	73.9	73.7	73.2	72.7

*1st 48 hours with untreated oil to produce dirty boiler surfaces; additive-treated oil burned for 2nd 48 hours.

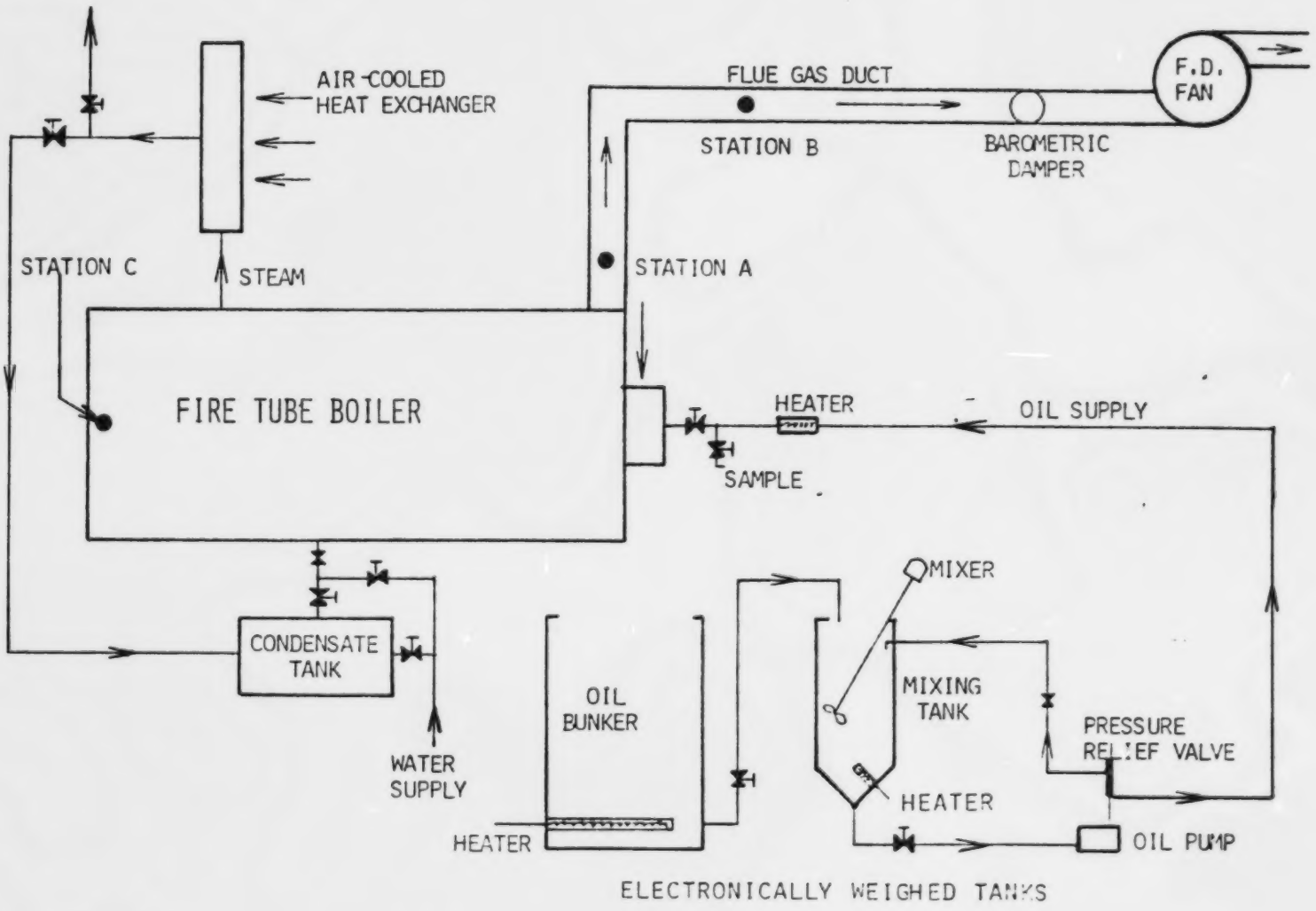

Figure 1. Schematic illustration of the packaged oil-fired boiler;additive tests.